When linearity prevails over hierarchy in syntax

Jana Willer Gold[a], Boban Arsenijević[b], Mia Batinić[c], Michael Becker[d], Nermina Čordalija[e], Marijana Kresić[c], Nedžad Leko[e], Franc Lanko Marušič[f], Tanja Milićev[g], Nataša Milićević[g], Ivana Mitić[b], Anita Peti-Stantić[h], Branimir Stanković[b], Tina Šuligoj[f], Jelena Tušek[h], and Andrew Nevins[a,1]

[a]Division of Psychology and Language Sciences, University College London, London WC1N 1PF, United Kingdom; [b]Department for Serbian language, Faculty of Philosophy, University of Niš, Niš 18000, Serbia; [c]Department of Linguistics, University of Zadar, Zadar 23000, Croatia; [d]Department of Linguistics, Stony Brook University, Stony Brook, NY 11794-4376; [e]Department of English, Faculty of Philosophy, University of Sarajevo, Sarajevo 71000, Bosnia and Herzegovina; [f]Center for Cognitive Science of Language, University of Nova Gorica, Nova Gorica 5000, Slovenia; [g]Department of English Studies, Faculty of Philosophy, University of Novi Sad, Novi Sad 21000, Serbia; [h]Department of South Slavic languages and literatures, Faculty of Humanities and Social Sciences, University of Zagreb, Zagreb 10000, Croatia

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Hierarchical structure has been cherished as a grammatical universal. We use experimental methods to show where linear order is also a relevant syntactic relation. An identical methodology and design were used across six research sites on South Slavic languages. Experimental results show that in certain configurations, grammatical production can in fact favor linear order over hierarchical structure. However, these findings are limited to coordinate structures and distinct from the kind of production errors found with comparable configurations such as "attraction" errors. The results demonstrate that agreement morphology may be computed in a series of steps, one of which is partly independent from syntactic hierarchy.

experimental syntax | syntactic agreement | elicited language production | coordinated noun phrases | South Slavic languages

In this article we study the phenomenon of syntactic agreement, a core linguistic dependency relation that is found across human languages and governed by regular, widespread, and consistent principles of grammatical organization (1, 2).

Since the demonstration of patterns of auxiliary inversion in English highlighted by ref. 3 and later by ref. 4, it has been a staple of the field that syntax refers to hierarchical, not linear order as learners prefer hierarchically based generalizations. For example, when forming a yes–no question based on the declarative sentence "The woman who has coffee is happy," the verb that moves to the beginning of the sentence is the hierarchically highest, and not the linearly closest, thus forming "Is the woman who has coffee happy?" and not the ungrammatical "Has the woman who coffee is happy?" Nonetheless, in work such as ref. 5, it was shown that South Slavic languages can show agreement based on linear order: When the subject contains two noun phrases (NPs) that are conjoined, the verb can sometimes agree with the linearly closest one (even if it is the second NP). Coordinations therefore offer an opportunity to examine whether agreement morphology may operate with its own principles, partially distinct from those of other syntactic relations, where the norm is reliance on hierarchical relations.

The structure of coordinated phrases has a long history in the language sciences, where in the philosophy of language and semantic theory, it is treated as a symmetric operator (6, 7), whereas research in syntactic theory has developed extensive evidence that the internal structure of coordinations is asymmetric and hierarchical (8–11) (Fig. 1). Given this latter structure and the scarcity of purely linear-order relations within syntax, it is expected that the two conjoined noun phrases would not be equally possible agreement controllers. Yet a number of studies have recently argued (12–15) that linear order is a relevant relation for syntactic operations specifically when it comes to coordinated phrases, as they are headed by neither one of the conjuncts.

In parallel within the field of psycholinguistic studies of agreement in language production, ref. 16 found that English speakers show cases of agreement based on linear order, called "attraction," with the plural complement of noun phrases (e.g., the key to the cabinets are missing), a set of findings later replicated in comprehension and across a variety of other languages and considered partly grammar based but partly the result of error. The question we set out to investigate, therefore, was how experimentally robust is linear conjunct agreement in South Slavic morphosyntax? Given the important consequences of linear order mattering for the computation of agreement, it is imperative to show that the relevant patterns in South Slavic cannot be reduced to "performance errors."

In South Slavic languages with three genders, when feminine (F) and neuter (N) are combined in a preverbal subject (as in example *ii*), there are two potential nondefault controllers of agreement, thereby posing a grammatical conflict in terms of whether verbal morphology should reflect hierarchically based or linearly based agreement. South Slavic languages are also an ideal set of languages to address this question because of the variable position the subject can take relative to the verb (as shown in examples *i* and *ii*). Closest conjunct agreement—i.e., verbal agreement with the linearly closer of two conjuncts in a coordinated noun phrase, in cases such as example *i*—has been widely attested for postverbal subject noun phrases that are coordinated (17, 18), but there is much less cross-linguistic evidence

Significance

Syntactic distance is standardly measured hierarchically only by counting the nodes in a tree-like structure. The dominance of hierarchy over the other logically possible measure of distance—e.g., counting words in a linear order—stems from a large body of research. We show a strong preference for the linear strategy in coordination structures in South Slavic languages, with a design comparing agreement controllers that can come either before or after their target. A large-scale study over six geographically and linguistically distinct varieties discovered remarkable uniformity in this preference. Variation discovered was mostly intraindividual, strongly suggesting that a language can entertain synchronous "multiple grammars," the most striking of which is the one requiring direct reference to linear order.

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[1]To whom correspondence should be addressed. Email: a.nevins@ucl.ac.uk.

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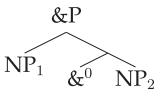

Fig. 1. Hierarchical structure of coordination (9–11).

for closest-conjunct agreement in preverbal cases such as example *ii*. In South Slavic languages, both are possible, as shown in these examples from Bosnian/Croatian/Serbian:

i) Jučer su odštampan**e** molbe i rješenja.
yesterday were printed.F.PL request.F.PL and decision.N.PL
'Yesterday, requests and decisions were printed out.'

ii) Molbe i rješenja su odštampan**a** jučer.
request.F.PL and decision.N.PL were printed.N.PL yesterday
'Requests and decisions were printed out yesterday.'

N.PL, neuter plural; F.PL, feminine plural.

An earlier study (14) demonstrated that all three options—agreement with the first conjunct, agreement with the second conjunct, and default masculine plural agreement—are used in Slovenian. Here we broaden the scope of investigation to the entire western South Slavic linguistic branch shown in Fig. 2 to verify the robustness and replicability of the phenomenon. These languages are an ideal testbed for comparison of language distances and changes in progress as they include Slovenian as well as three varieties that until recently were considered a single language (Serbo-Croatian or Croato-Serbian), but with the dissolution of former Yugoslavia have become official national languages with independent prescriptive norms that occasionally aim to widen the gap between neighboring varieties, typically in the domain of the lexicon.

Experiments

Three experiments were conducted. The methodology used in experiments 1a and 1b, elicited production, involved coordinated noun phrases. In elicited production, participants first see a model sentence, such as *Prevod je ovjeren pečatom*, "The translation [masculine singular (M.SG)] was authenticated (M.SG) by seal." They then see a replacement noun phrase, a coordinated phrase (&P) in the target conditions, displayed onscreen, as *Molbe i rješenja*, "requests (F.PL) and decisions (N.PL)." After seeing the replacement noun phrase, they were asked to substitute the subject of the model sentence with the replacement phrase and produce the new complete sentence, e.g., *Molbe i rješenja su ovjeren-i/-a/-e pečatom*, "Requests (F.PL) and decisions (N.PL) were authenticated (M.PL/N.PL/F.PL) by seal," where the dependent variable is the gender ending they place on the verb in this new production. Responses were recorded, classified, and tabulated. Additionally, production latency until they continued to the next item was measured.

As an independent variable we included all nine &P combinations of the three genders, with six items per condition. The NPs involved were always inanimate and plural, and the dependent variable was the gender agreement on the participle. Inanimates were chosen to allow all three genders to potentially control agreement based on their position, without interference of semantic preferences for animacy-based gender. Plurals were chosen to ensure a match between the number of each individual conjunct and that of conjunction as a whole. We used 54 distractor items (18 relative clauses, e.g., "the table that was broken"; 18 quantified noun phrases, e.g., "12 chairs"; and 18 "hybrid" nouns, e.g., ones with mismatching morphological and semantic gender). Experiment 1a focused on SV configurations (preverbal subject NPs), with 30 participants at each of the six sites as shown in Fig. 2. Experiment 1b focused on VS configurations (postverbal subject NPs) of the same conditions, again with $n = 30$ at six sites.

Experiment 2 was a speeded acceptability judgment test where participants were presented with a total of 138 sentences. Sixty-four were experimental stimuli, alongside 64 distractor items and an additional 10 anchoring items to allow participants to establish clear endpoints of the grammaticality scale. Half of the experimental items were SV and the other half VS. There were eight conditions placed in both SV and VS configurations [all gender combinations except masculine (M)+M] and two sentences per condition. The stimuli were identical to those elicited in the production study. Twenty native speakers at each of six sites, with the same criteria outlined above, rated each agreement structure with a judgement from 1 to 5 for its degree of acceptability.

The design and methodology of the three experiments were identical across sites, with local adaptation of vocabulary and morphosyntax orthogonal to agreement. Participants were ages 18–22 y, were not linguistics students, and were native speakers who grew up in the region tested.

Results

The "default" value for conjuncts with mixed genders is M plural, and this is an option that is often suggested in prescriptive grammars, presumably avoiding the choice of privileging the gender of either conjunct and rather opting for a default (or "last resort") value for the conjunction as a whole. Thus, for example, when an &P in preverbal position has a combination such as N + M, and we see M agreement on the verb, we cannot tell whether it is default or closest conjunct agreement. However, in the combinations N + F and F + N, there are three distinct options: first-conjunct agreement (hierarchical), closest-conjunct agreement (linear), and default agreement. Note that in postverbal (VS) contexts, the first conjunct is the closest conjunct. In SV contexts, therefore, linear agreement favors the second conjunct, while hierarchical agreement favors the first conjunct, as shown in Fig. 3, *Left*. In VS contexts, neither strategy favors the second conjunct, as shown in Fig. 3, *Right*.

Linear Agreement Is Robust Across All Sites. The results showed that linear agreement was robustly found across all sites, as shown in Fig. 4 for the preverbal [N&F] and [F&N] conditions. In fact, linear agreement trumps hierarchical agreement at least three times to one, across all six sites.

These results establish that closest conjunct agreement is greatly preferred to highest conjunct agreement. As noted above, however, default agreement (e.g., M plural) is an additional last resort strategy available to speakers alongside highest and

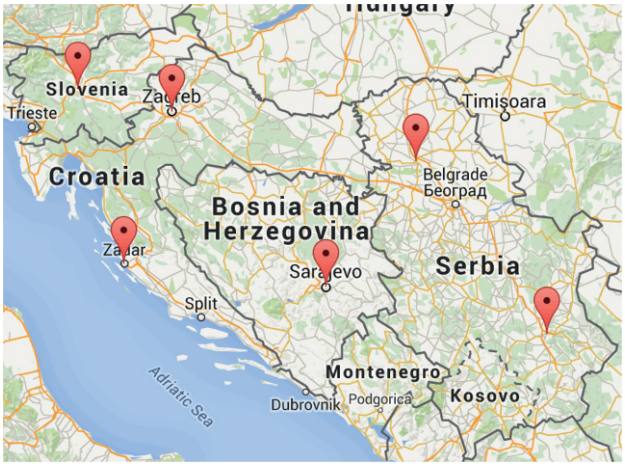

Fig. 2. Research sites for the South Slavic comparison. Map was created with R's ggmap package, using Google Maps data.

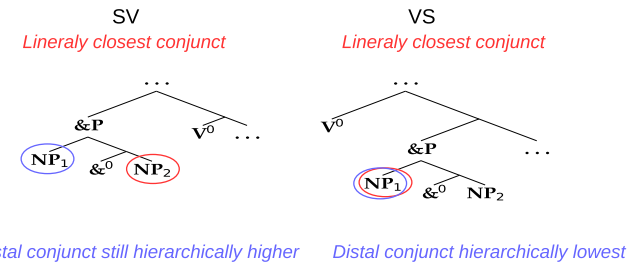

Fig. 3. Highest (blue) vs. closest (red) agreement in &Ps. In SV (*Left*) (preverbal), these two strategies are distinct, whereas in VS (*Right*) (postverbal) they converge.

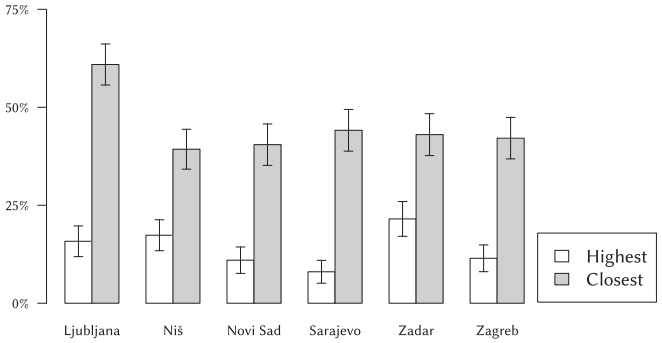

Fig. 4. Rates of hierarchically based (highest) vs. linearly based (closest) agreement for [N&F] and [F&N] conditions, preverbally (n = 180), with average percentage of choice shown per site with SE of mean bars.

closest conjunct agreement (thereby responsible for the additional rates of responses adding up to 100%). Our research question is specifically on hierarchical vs. linear choices among the two conjuncts as nondefault strategies.

For the phenomenon of production of choosing a conjunct for agreement, linear agreement controllers are often preferred to hierarchically based ones. Within the same study, we measured the production latencies for all nine conditions. Suppose that all three options (highest, closest, and default) are compared in terms of Shannon entropy computed over the production responses, whereby the greatest uniformity of production is found in [M&M] configurations with the lowest Shannon Entropy of 0.002, as for this condition, linear, hierarchical, and default strategies all yield the same outcome. The next level of complexity is MN, NM, MF, FM, where default always matches one other strategy. Finally, FN/NF is the most divergent situation. We compared the overall average production time in milliseconds for each of the nine conditions and found an overall strong correlation $\rho = 0.90$, $P < 0.005$ for the SV conditions. These results are compatible with models in which participants, when they have more than one choice of agreement controller, literally take more time to choose among them. Thus, the [N&F] and [F&N] conditions have the highest overall average for production latency, as shown in Fig. 5. These results are compatible with claims such as ref. 19, where grammatical flexibility is found to increase latency, and more generally indicative of models whereby individual speakers entertain simultaneous "multiple grammars" that compete during real-time production (20–23).

Let us consider two alternative interpretations for the apparent preference for linearity over hierarchy in agreement controllers given coordination. One would be to analyze default agreement (e.g., M plural in N + F or F + N combinations) as a kind of hierarchically based choice, reflecting the features that are computed by the coordination as a whole on the basis of each conjunct in cases of conflict (24), rather than as a last resort (as proposed herein). However, empirically we found that the rate of default agreement drastically plummets in postverbal conditions, as Fig. 6 shows. By hypothesis, this is because "hierarchical" agreement and "linear" agreement as used here refer to the conjuncts within the coordination themselves. As these two agreement controller strategies both converge on the first conjunct in postverbal structures, there are two distinct production strategies that both yield first-conjunct, i.e., nondefault, agreement. The rate of default agreement is much lower in postverbal structures than it is in preverbal structures, confirming that linear agreement truly wins out—and that default M plural agreement is not a hierarchically based choice. The second interpretation would be to claim that there is no particular preference for linear vs. hierarchical agreement in terms of conjuncts themselves, but that the first conjunct wins out in preverbal cases because it is the very first item in the sentence. However, the extremely high rate of linear agreement in postverbal structures provides evidence that there is no particularly special role for the first item in the sentence as a privileged controller and rather that the choice is between highest and closest within the coordinated noun phrase itself.

Production studies offer a direct view of the grammatical strategies speakers arguably prefer. Nonetheless, it is important to confirm that the results of production studies line up with speakers' judgments of what would actually be acceptable. Therefore, we conducted experiment 2, a rating study. The results, shown for the SV conditions in Fig. 7, show that linearly based conjunct agreement is most highly rated—particularly when the controller of agreement is also an M noun, as in the [F&M] and [N&M] conditions, where either closest agreement or default agreement would deliver the result of M agreement on the verb. The next highest-rated strategies are default agreement and closest conjunct agreement with a second conjunct that is either F or N, as in the [N&F], [F&N], [M&N], and [M&F] conditions. The third highest-rated strategy, lower than all of these previous ones, is in fact highest conjunct agreement, confirming the production results that, at least for preverbal conjunct agreement, hierarchical controller generally loses out to a linearly closest controller. Nonetheless, as Fig. 7 shows, hierarchical agreement is still rated more highly compared with agreement with a feature completely absent from the conjunct altogether, indicating that the former is indeed a grammatically possible strategy.

Linear Agreement Is Distinct from Attraction. As stated above, the finding that a linearly closer controller for agreement is chosen over a hierarchically closer one is surprising, given the

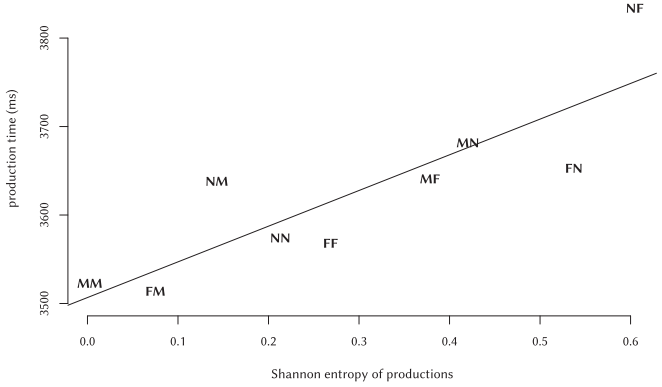

Fig. 5. Production time is significantly correlated with uniformity of productions for the nine gender combinations in the SV condition (where highest and closest agreement diverge), n = 180. In a fully crossed mixed-effects regression, Shannon entropy of responses significantly predicts production time, β = 86, $t = 4.10$, $P < 0.0001$.

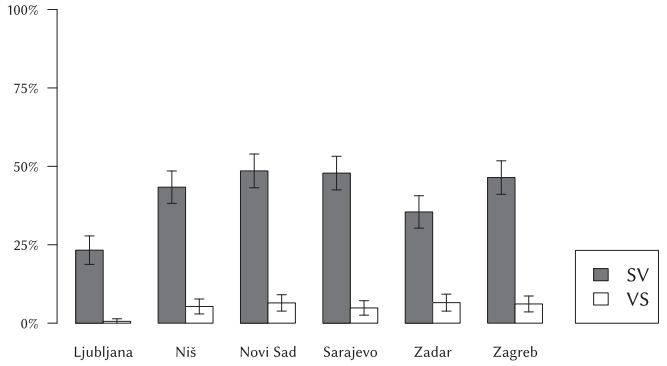

Fig. 6. Rates of default agreement in SV (preverbal coordination) vs. VS (postverbal coordination) structures. Default agreement is produced significantly more often in SV structures than it is in VS structures (41% vs. 5%, fully crossed and centered logistic mixed-effects linear model, $t = 11.72$, $p < 0.0001$).

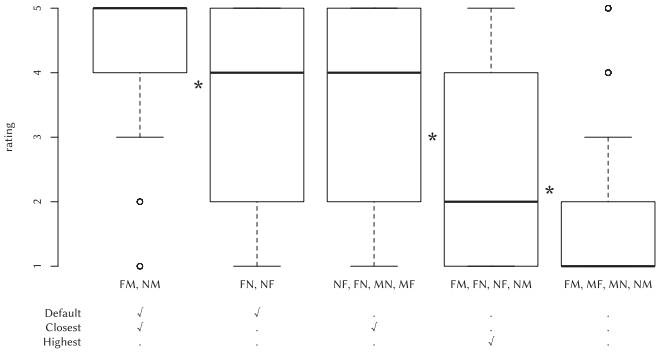

Fig. 7. Acceptability ratings for agreement as controlled by the closest (M), default, closest (F or N), highest, or no conjunct ($n = 120$), modeled as a fully crossed mixed-effects regression with a five-level Helmert-coded predictor. The combination of default and closest agreement is rated significantly higher than default agreement only. Closest agreement is rated significantly higher than agreement with highest, which in turn is rated higher than the baseline lack of agreement. All significant differences marked with * between the relevant columns.

longstanding demonstration that syntactic operations, and indeed learners, typically prefer hierarchical over linear generalizations. At first blush, it might be tempting to relate our findings to the kind of performance errors found in agreement-attraction production studies such as "The key to the cabinets are missing" (16, 25); see also ref. 26 for an overview of comprehension studies. However, the rate of linear agreement obtained in our results is much higher than that usually found in production studies of attraction [around 13%, in a metaanalysis of 16 studies (27)], suggesting it is a distinct phenomenon. In fact, we included attraction configurations as well, to compare the two kinds of structures, using the same elicited production technique; for example, the model sentence *Reklama je emitovana na radiju*, "The advertisment (F.SG) was broadcasted (F.SG) on the radio," was paired with a replacement phrase featuring a postverbal subject in a relative clause, such as *Pitanje koje su postavili slušaoci*, "The question (N.SG) that had asked (M.PL) the listeners (M.PL)," where the M plural is linearly most rightward, but not hierarchically highest. The substitution could thereby potentially result in linearly based attraction, such as *Pitanje koje su postavili slušaoci su emitovan-i na radiju*, "The question that the listeners (M.PL) had asked (M.PL) were broadcasted (M.PL) on the radio." Nonetheless, as Fig. 8 shows, linear agreement is greatly overshadowed by hierarchical agreement in these attraction configurations, in stark contrast to the conjunct agreement results in Fig. 4. Comparison of the rate of highest conjunct agreement in coordination structures vs. its rate in attraction configurations was significant in a fully crossed mixed-effects logistic regression ($z = 28.92$, $P < 0.0001$), consistent with the interpretation that linear agreement is distinct from agreement attraction in these languages and possibly beyond.

Why should attraction show the expected preference for hierarchical effects, whereas conjunction shows a preference for linear effects? We contend that the crucial factor is that the first conjunct in an &P is not the head of the &P and that hierarchy "fails" given the details of the structure of the &P. The two structures are compared in Fig. 9, where it can be seen that given a coordination structure, the higher NP_1, is not the head of the whole phrase, and there is thus no reason for agreement to respect the hierarchy. By contrast, in an attraction structure based on a relative clause, the noun projecting the higher NP_1 is the head of the whole phrase, and agreement is therefore forced to respect the hierarchical structure. In short, the difference is that an &P is not headed by NP_1, whereas an attraction structure is headed by the noun projecting NP_1, and that makes all of the difference.

However, at this point, the fact that NP_2 has been overwhelmingly chosen as a controller for agreement over NP_1 with preverbal subjects (compare Fig. 4) might lead one to ask whether &Ps have any internal hierarchical structure at all. Indeed, if &Ps lacked internal hierarchical structure, the entire question of whether linearity trumps hierarchy becomes moot. However, there is incontrovertible evidence based on our results that &Ps have internal hierarchical structure, as found in the comparisons between SV (preverbal) and VS (postverbal) structures. To see why this is so, consider what the results would be like if &Ps were flat structures, as shown in Fig. 10. If &Ps were flat, there should be no difference in the rate of agreement with NP_1 in preverbal structures vs. the rate of agreement with NP_2 in postverbal structures, as both are distal conjuncts (i.e., linearly farther away from the verb than the other conjunct), but both are "equally far" from the verb. By contrast, given a hierarchical structure for &Ps as in Fig. 1, there should be a difference in the rate of agreement with NP_1 in preverbal structures, which are still hierarchically favored, vs. the rate of agreement with NP_2 in postverbal structures, which are neither linearly nor hierarchically favored.

The results demonstrate an asymmetry: NP_1 agreement in SV structures is greatly preferred to NP_2 agreement in VS structures. Hierarchical structure is the way to encode asymmetry: Without hierarchy, structures would be flat, symmetric, and equally (dis)preferable for the distal conjunct, and recall that in the elicited production design, participants saw the entire conjunction separately before producing VS agreement. Nonetheless, in both production and perception, NP_1 agreement in SV

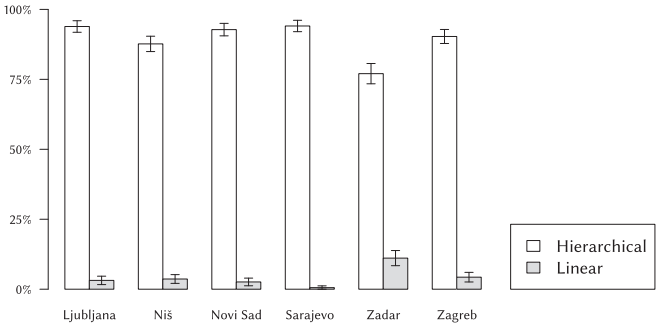

Fig. 8. Rate of hierarchically based (highest) vs. linearly based (closest) agreement for attraction configurations, with average percentage of choice shown per site with SE of mean bars.

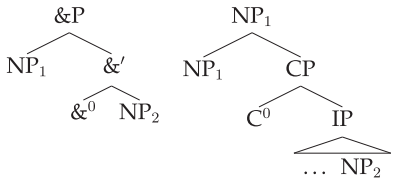

Fig. 9. Comparison of the relative positions of NP_1 and NP_2 in coordination (*Left*) vs. attraction (*Right*) structures.

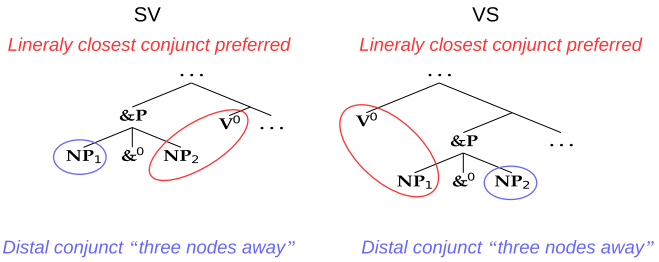

Fig. 10. Expected differences between SV and VS conditions if &Ps were flat.

structures is greatly preferred to NP_2 agreement in VS structures, as shown in Fig. 11.

Thus, while linear agreement is preferred over hierarchical agreement, as shown in Fig. 4, nonetheless, there is still a role for hierarchical agreement, as shown in Fig. 11. Coordination involves a hierarchical structure, but one that can nonetheless be overturned by linear factors, precisely because of the specific kind of headedness at stake in &Ps.

Discussion

Where can linearity override hierarchy? At least in one principled corner of the grammar, in one small corner of the world, it can. While postverbal closest-conjunct agreement has been well documented (28, 29), in preverbal position it is demonstrably a case where linear factors override hierarchical ones, and we have argued this is due to the specific structure of coordinations. Experimentally elicited results of this type lend credence to the necessity of admitting linear effects into syntactic computations of distance; see also refs. 13, 30, and 31 for closest-conjunct agreement in gender. For coordinations, linearly based agreement proved the most common, the most readily available, and the highest-rated agreement pattern. As such, it is a clearly different phenomenon than attraction errors. A current research focus is how to model the variability in agreement strategies within a restricted model of possibilities, with some efforts entirely within classic models of hierarchical syntax (32, 33). We contend that the results favor an approach according to which agreement is a syntactic operation that is split into multiple stages of operations (14, 27). In particular, suppose that one earlier stage of the computation, relevant for the interface of syntax with semantics and logical form, establishes a grammatical link only between two phrases, while the second stage, relevant for the interface of syntax with morphological form, then copies the features from a controller to the target to realize its specific phonological form, during a later stage of computation. If other operations, in particular, determination of linear order, may vary in where it is applied with respect to these two stages, this accounts for the individual variation in the order of operations yielding the multiple agreement patterns outlined above. As such, these results are compatible with models of grammar in which linear information enters only very late into syntactic computations (34).

Such a model allows us to address the question of why linearly based agreement occurs only for gender. Number information is highly relevant for semantics of both nominal and verbal interpretation (35, 36) and can be deterministically computed in a conjunction, whereby two singulars compose a plurality. Grammatical gender, on the other hand—particularly for inanimate nouns, the stimuli used herein—has no semantic import whatsoever and can therefore be delayed until this second stage of the agreement computation, at the interface to morphophonology, where linear order becomes more predominant in representation and processing.

Materials and Methods

Research Institutions. The three experiments (1a, 1b, and 2) were carried out at six research institutions: University of Nova Gorica (tested also at University of Ljubljana), Slovenia; University of Zagreb and University of Zadar, Croatia; University of Sarajevo, Bosnia and Herzegovina; and University of Novi Sad and University of Niš, Serbia. A single experimental design and procedure was implemented across all six research institutions, each of which conducted their experiments under the general institutional approval for behavioral experiments with healthy adult individuals tested for linguistics and the language sciences.

Language. The language used in the experiment was adapted to the research institutions' local neutral varieties. Experimental material was first created in the neutral variety of Zagreb Croatian and was later adapted to the target language variety, i.e., those of Zadar, Sarajevo, Niš, and Novi Sad. The adaptations were minimal to ensure uniformity across research locations. They were mostly lexical due to variation in gender of specific lexical items. For Slovenian, a parallel set of materials was created to avoid any gender mismatches that could have resulted from literal translation.

Participants. In experiment 1, 30 first- or second-year students [sex: females (F) = 75%, males (M) = 25%] (age: mean = 18.65 y) participated in the experiments at each of the six research institutions. Each participant was tested on experiment 1a and experiment 1b in two experimental sessions 1 wk apart, with the exception of Slovenian, where for logistical reasons different participants were recruited for experiments 1a and 1b. They were all native speakers of the local language variety, attended the local secondary school, and were not pursuing a university degree in the study of the local language. Either their participation was voluntary or they received course credits for their participation. For experiment 2, we recruited altogether 133 undergraduate students (between 20 and 25 per site) of comparable demographics (sex: F = 64%, M = 36%) (age: mean = 20.28 y).

Design and Materials. Experiments 1a and 1b tested nine gender combinations preverbally (experiment 1a) and postverbally (experiment 1b). Three genders (masculine, feminine, and neuter) were entered in a 3×3

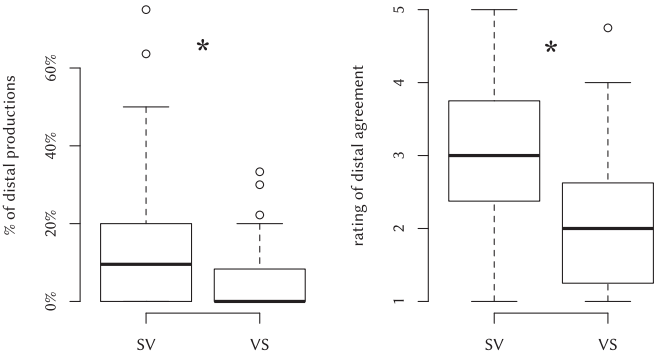

Fig. 11. Percentage of distal productions (*Left*) and ratings of distal agreement (*Right*) for preverbal vs. postverbal structures. Distal agreement in SV is produced significantly more often than it is in VS (14% vs. 3%, fully crossed and centered logistic mixed-effects linear model in lme4, $\beta = 1.72$, $t = 7.01$, $P < 0.0001$). Distal agreement in SV is rated significantly higher than it is in VS (3.02 vs. 2.00, fully crossed and centered mixed-effects linear model in lme4, $\beta = 1.02$, $t = 8.92$, $P < 0.0001$).

factorial design with the two conjuncts as factors. For each condition, 6 experimental items were created, amounting to a total of 54 stimulus items. Only inanimate plural count nouns were used in coordinations to ensure control over the number feature while manipulating gender and to avoid differences between neuter and nonneuter genders in the potential influence of biological gender. The nouns that were conjoined were from the same semantic field and each one was individually compatible with the predicate in the model sentence. Nouns were carefully chosen not to form idiomatic coordinations or collocations with the verb or each other (see *SI Appendix, Experiment 1* for the full list of examples). An additional 54 fillers were used in the experiment that did not involve conjoined noun phrases. Participants were first presented a model sentence that used a simple nonconjoined masculine singular noun with a zero suffix both on the noun and on the agreeing verbal participle. All model sentences were made on the same template: Subject(Noun) + Aux + Participle + Preposition + Noun for experiment 1a and Preposition + Noun + Aux + Participle + Subject(Noun) for experiment 1b. Prepositional phrases (adjuncts) were added at the beginning or the end of the model sentence to fill in the slot in the intonation contour taken by the subject in the other condition and to make the postverbal condition sound natural. The mean length in characters of the model sentence and the conjuncts was the same across all nine conditions (model sentence mean, 28 characters with spaces/10 syllables; conjunction mean, 18 characters with spaces/8 syllables). Eighteen comprehension questions appeared after the replacement phrase to keep participants engaged. The number of comprehension questions was balanced across conditions.

Experiment 2 was a rating study in which 128 sentences were presented in random order, with 64 experimental items and 64 fillers. For the experimental items, the sentences from experiments 1a and 1b were chosen as the basis of design (see *SI Appendix, Experiment 2* for the full list of examples). There were 32 experimental conditions (16 postverbally, 16 preverbally), with 2 sentences for each. On top of the genders of the two conjuncts, another factor was the gender agreement shown on the verb. Participants were shown the sentence for 3,500 ms and were then asked to give an acceptability judgment for it on the next screen.

Procedure. In experiments 1a and 1b, participants were tested individually. Each participant was seated in a sound-isolated or quiet room. Examples were displayed on a monitor in black on a white background in 12-point font size. Materials were presented on the screen using IbexFarm (37), a free on-line experimental tool and platform. Participants were asked to read and produce the experimental sentences with a loud and clear pronunciation and were encouraged to speak at a natural pace. Response production was recorded by Audacity, using a built-in microphone, onto the computer in a .wav format. The digitally recorded responses were hand coded by native speakers according to their agreement endings and agreement features. Responses were coded as correct responses when the model sentence was correctly repeated and contained the inflected participle, the exact participle used in the model sentence, or a semantically similar one. Any second production of an inflected participle that differed from the first one as a result of autocorrection was transcribed but these were not considered in the analysis. Responses were coded as agreement errors when the sentence produced met all of the above criteria for correct responses but the participant produced ambiguous or unintelligible agreement. Responses were coded under miscellaneous responses when incorrect words were produced, the sentence was interrupted, word order was changed, or when no response was provided. Only uniquely correct responses were considered in the analysis.

Experiment 2 was conducted simultaneously by all participants at each site in a computer lecture room. Experimental trials were preceded by eight practice examples and 10 anchoring items varying in grammaticality. Anchoring items were used to allow participants to create a benchmark of grammaticality to be used on the experimental items that followed. For all experiments, consent forms and a comprehensive biographic questionnaire aimed to obtain information about the participants' native language variety were administered off-line.

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